§3. Excitation of Stable Alfvén Eigenmodes by Application of Alternating Magnetic Field Perturbations in CHS

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In existing tokamaks and helical devices, the instabilities of AEs are investigated using energetic ions produced by neutral beam injection (NBI), ion cyclotron resonance heating (ICRH) and DT reaction [1,2]. The stability of an AE is determined by competition between fast ion drive and damping mechanisms, and evaluated by the sign of the net growth rate $\gamma = \gamma_{drv} - \gamma_{damp}$. Here, γ_{drv} is the growth rate, and a linear growth rate is adopted for safety in stability evaluation. However, γ_{damp} is the total damping rate, which originates from various damping mechanisms involving bulk plasma and beam ions.

In the Compact Helical System (CHS), we have tried to excite AEs by applying alternating magnetic field perturbations with a set of electrodes inserted in the plasma edge, and measuring the damping rate. Small magnetic field perturbations perpendicular to the confinement magnetic field line are generated by an alternating current along the magnetic field line induced by a pair of electrodes inserted at the plasma edge, as shown in Fig. 1. The alternating current induced by the electrode(s) acts an excitation antenna. This electrode technique can excite shear Alfvén waves effectively[3]. Two electrodes are placed 180 degrees apart, in the toroidal direction, at the inner port of the toroidal vacuum vessel, and are excited by the respective power supply having 0 or π-phase difference to specify the toroidal mode numbers of the applied perturbation fields.

A typical operation of the electrode system is shown in Fig. 1[4]. The driving frequency of applied external perturbation was swept from 10 to 200 kHz in 0.1s to search for expected TAE gaps by the single electrode.

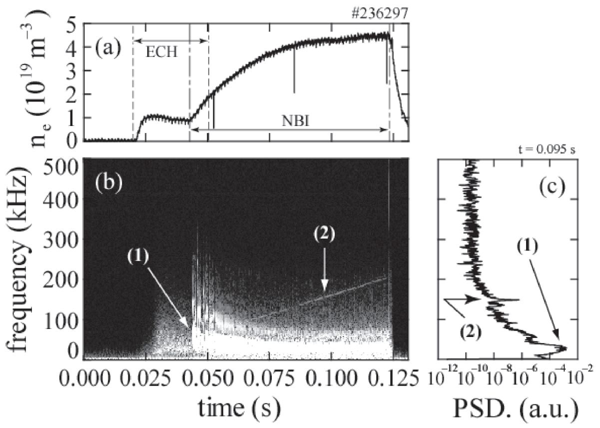

Fig.2 (a) Time evolution of line-averaged electron density in an NBI-heated hydrogen plasma, where B_t = 0.9 T. (b)Contour plot of poloidal magnetic fluctuations detected by a magnetic probe, where only a single electrode is employed for AE excitation. (c) Power spectrum of magnetic fluctuations calculated in the time window of t = 0.095-0.096 s. The arrows (1) and (2) in Figs. 1 (b) and 1 (c) indicate energetic-ion-driven modes and response to the externally applied perturbations, respectively.

The frequency response signal called as transfer function G(ω) is obtained experimentally as the ratio of the magnetic probe signal to the antenna current signal, as shown in Fig. 3. Eigenfrequency and growth rate of TAEs will be obtained by the fitting with a model function such as a general viscous damping system. In this case, the resonant frequency related to TAE and the damping rate are obtained as f_o = 153±6 KHz and γ/ω = 18±5%, respectively. The calculation of n=1 shear Alfvén continua, including the effect of toroidicity, implies that this mode can be identified as the n=1 TAE for the gap generated by m = 1 and 2 mode coupling.

[1] A. Fasoli *et al.* : Nucl. Fusion **47**, S264 (2007).
[2] K. Toi *et al.* : Nucl. Fusion **39**, 1929 (1999).
[3] G. Matsunaga *et al.* : Phys. Rev. Lett. **94**, 225005 (2005).
[4] T. Ito *et al.* : Plasma Fusion Res. **3** 033(2008)

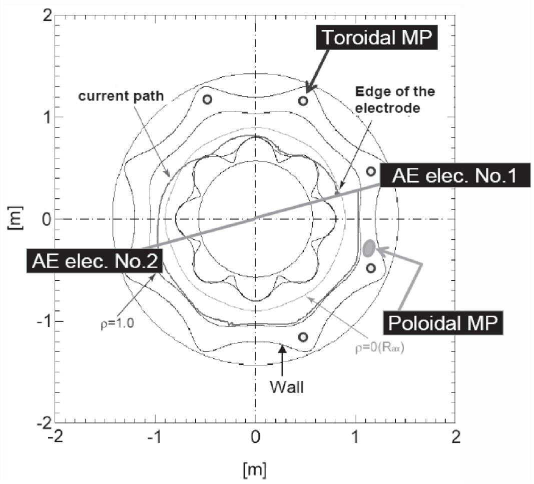

Fig. 1 Experimental setup of AE excitation experiment in CHS. Plan view of the vacuum vessel wall, the last closed flux surface and the expected current path showed as solid line. The two electrodes are installed at the locations marked with "AE elec. No. 1" and "AE elec. No. 2". Each position of the toroidal and poloidal magnetic probe array are also drawn as small circles.

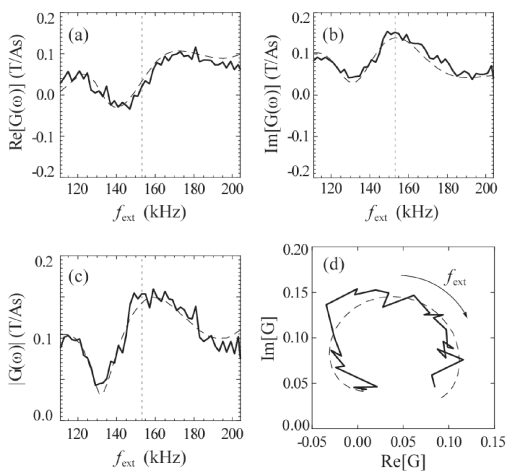

Fig. 3 Experimentally obtained (solid curve) and fitted (broken curve) transfer functions, shown as a function of the driving frequency f_{ext}. (a) Real part, (b) imaginary part, and (c) absolute value of the transfer function. (d) Nyquist plot drawn around the resonance peak from f_{ext} = 120 kHz to f_{ext} = 180 kHz.